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Analysis on dynamic ecological security and development capacity of 2005-2009 in Qinhuangdao, China

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Abstract

According to principles and methods of the ecological footprint, a time series of the ecological footprint was measured between 2005 and 2009 in Qinhuangdao City. The results showed that per capita the ecological footprint of Qinhuangdao City declined 3.56% from 1.847040hm² per person to 1.781227hm² per person in the past 5 years. However there is no significant change in per capita ecological carrying capacity with upward trend overall. Ecological deficit in Qinhuangdao increased year by year. The ecological security was at level. The pressure on the ecosystem of Qinhuangdao is so large that the economic and social developments were in a state of unsustainable development. Ecological footprint diversity of Qinhuangdao during 5 years was measured according to different land types and development capacity of Qinhuangdao was analysed by Ulanowicz formula of the development capacity

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1. Introduction

The method used to find ecological footprint is to measure the regional ecological security by calculating the human consumption of natural resources and carrying capacity of natural resources capital. Ecological Footprint Theory (EFT) was first proposed in 1992 by the Rees [1], mainly used to calculate the biologically productive areas needed for human beings' natural resources to maintain their own survival and for absorbing wastes in certain population and economies of scale. The area is compared with its ecological capacity of the region to determine whether the development of the region's ecological capacity is within the safe range. When the ecological footprint is greater than ecological capacity the result is ecological deficit, indicating the region's sustainability is weak; on the contrary, when the ecological footprint is less than capacity there is an ecological surplus, which indicates a strong sustainability of this region [2].

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EFT was used to calculate a series of index in Qinghuangdao during 2005-2009 including ecological footprint, ecological carrying, ecological deficit / surplus, ecological security, ecological footprint diversity and development capacity. The data helped to reveal the situation of the ecological economy sustainable and the change process of resources using intensity so as to seek ways to achieve sustainable development within resources environmental carrying capacity in Qinhuangdao.

2. Study area

Qinhuangdao is located in Hebei Province, N 39 ° 24 ' ~ 40 ° 37', E 118 ° 33 ' ~ 119 ° 51'. It contains three municipal districts of Beidaihe, Shanhaiguan and Haigang district and four counties of Funing, Changli, Lulong and Qinglong with the total area of 7812.4 km² and population of 2.87 million. Located in a zone of warm temperates and impacted greatly by sea, the climate of Qinhuangdao is milder. Dry and less rainfall in spring; tepidity without intense heat in summer; delightfully cool in autumn and not severely cold in winter. The average annual temperature is 11.2 °C, and annual rainfall is 551.7mm.

3. Methods

3.1 Calculation method

3.1.1 Ecological footprint model

The ecological footprint formula can be written as [3] :

$$EF = N[ef = \sum(aa_i) = \sum(c_i/p_i)] \quad (1)$$

Where: i = consumer goods categories, P_i = the first i kind of consumer goods the average production capacity, c_i = consumption of i^{th} commodity per capita, aa_i = corrected production land area per capita, N = population, ef = ecological footprint, per capita EF = general ecological footprint.

3.1.2 Ecological carrying capacity model

Ecological carrying capacity formula can be written as:

$$EC = (1 - 0.12) \times ec \times N \quad ec = a_i \times r_j \times y_i (j = 1, 2, 3, \dots, 6) \quad (2)$$

Where: ec = ecological carrying capacity per capita; ai = biological production area per capita, rj = balanced factor; yi = yield factor, EC = ecological carrying capacity of the total population of area; N = the population. According to the world environment development committee (WCED) report, ecological carrying capacity calculation should be deducted 12% of biodiversity conservation area in an ecosystem.

3.1.3 Ecological security evaluation model

Analyze the ecological security from ecological carrying capacity and the ecological pressure. Ecological pressure index T model:

$$T = EF/EC \quad (3)$$

Ecological security grade is divided according to the size of the ecological pressure index. Specific correspondence see table 1.

Table 1 Eco-security evaluation based on ecological pressure index

Security level	Security status	Ecological pressure index
	Ideal condition	$T \leq 0.5$
	Safe	$0.5 \leq T \leq 0.8$
	Safer	$0.8 \leq T \leq 1$
	Unsafety	$T \geq 1$

3.1.4 Ecological footprint diversity model

Ulanowicz proposed the terms of systematic carrying capacity and systematic diversity in 1986, the system carrying capacity (SCC) refers to the total energy flow production. Development ability formula of Ulanowicz [4] was used to analysis sustainable development ability of regional system further. Ecosystem diversity can be calculated by Shalmo - wiener formula [5], which is written as:

$$H = -\sum_{j=1}^6 p_j \ln p_j \quad (4)$$

Where: H = the diversity index, P_i = proportion of i land type in total ecological footprint; Ecological footprint diversity contains two components: (1) abundance (using number of different land types); (2) fair degrees (distribution of ecological footprint measurement). Shannon-Weaver formula is not a monotonic function, which means the more equal the ecological footprint distribute in ecological economic system, the higher the diversity is for a ecological economic system given components

3.1.5 Ecological economic system development capacity model

Development capability can be obtained from multiplying ecological footprint by diversity of ecological footprint derived from the system organization. According to Ulanowicz formula, development ability can be written as:

$$C = EF \left(-\sum_{j=1}^6 p_j \ln p_j \right) \quad (5)$$

Where: C = development ability, EF = ecological footprint of the country or region.

3.2 Index and data

In this study, biological resources account includes 15 types of food, beans, potato, oil, cotton, vegetables, fruits, wood, pork, beef, mutton, poultry, eggs, milk products and aquatic product. Fossil energy account includes 10 types of coal, coke, crude oil, petrol, kerosene, diesel, gas, oil, electric power and heating power. The land use type includes 6 types of cultivated land, grassland, forest land, building land, fossil energy land and water. The index of biological resources account and fossil energy account derived from statistical yearbook of Qinhuangdao for 2005-2009. Yield per unit area of all kinds of natural resources and heating value index of energy per unit area were subjected to the data of Chinese part of FAO (Food and Agriculture Organization).

4. Results and discussion

4.1 The status of sustainable development and ecological foot-print in Qinhuangdao during 2005-2009

Ecological footprint per capita of Qinhuangdao ranged from 1.847040 hm^2 to 1.781227 hm^2 during 2005-2009 and showed ascending trend overall with total growth of 0.232323 hm^2 and annual growth rate

of 4.77 % (Table 2). Of which the ecological footprint between 2005 and 2006 felled slightly from 1.847040 hm^2 to 1.548904 hm^2 . In our studies, grassland and water ecological footprint had the maximum contribution for ecological footprint per capita of Qinhuangdao, accounted for 44% and 27% of total ecological footprint, respectively. That indicates the rapid economy development of Qinhuangdao and obvious improvement of the people's life resulting in great demand and consumption of meat, eggs and seafood. Demand for biological production is strong in Qinhuangdao within the obvious economic growth stage. Ecological footprint per capita of building lands increased 0.0071767 hm^2 , also indicates the rapid economic development of Qinhuangdao and ecological footprint of electricity and heating power increased greatly. During the same period of 5 years, ecological footprint of cultivated land growth rate changed rarely with 0.028664 hm^2 , however ecological footprint of forest land increased greatly with 0.093775 hm^2 , that explains people's dietary structure changed for the proportion of grain continuously decreased but proportion of meat, dairy and fishery products increased. The results can well explain the increasing of ecological footprint per capita of grassland. Ecological footprint fossil land reduced 0.0164231 hm^2 , that indicates with the development of ecological city construction of Qinhuangdao, the ecological environment is improved further and environmental protection consciousness of residents are strengthened constantly.

Comparing with the ecological footprint per capita in corresponding years of 2005-2009 (Table 2), there is no significant change in ecological carrying capacity per capita of Qinhuangdao with ascending trend overall. The ecological deficit increased gradually from -1.070972 hm^2 to -1.271515 hm^2 . Qinhuangdao was in an unsustainable development state during 2005-2009 (Figure 1). That indicates the consumption of Qinhuangdao's natural resources had increased, and conflicts between the ecological footprint and ecological bearing capacity expanded gradually. Furthermore, the ecological deficit per capita exceeded 0.4000 hm^2 of global ecological deficit per capita in recent 5 years. Consumption demand per capita of Qinhuangdao went greatly beyond the regeneration abilities of natural systems. It is warned that the current development of Qinhuangdao is at the costs of consuming stock of natural resources. Its development was in an unsustainable state of ecosystem.

4.2 Evaluation on ecological safety of Qinhuangdao during 2005-2009

It is clear that ecological pressure index of Qinhuangdao was (Table 2) security level which was in unsafe state. The main reason is that ecological occupation increased fast for ecological footprint per capita which is more than three times as many as ecological capacity per capita available. The ecological deficit was much larger than ecological capacity so that recovery flexibility of the ecological systems was destroyed that caused insecurity of ecosystem.

Table 2 Results of EF (per capita) and EC (per capita) calculation of Qinghuangdao city during 2005- 2009

year	Ecological footprint (per capita)					Ecological carrying capacity(per capita)						
	Arable land	Forest	Grass land	Building land	Fossil energy	water area	Arable land	Forest	Grass land	Building land	CO ₂ absorption	water area
2005	0.418843	0.115724	0.845764	0.003346	0.051600	0.411763	0.310417	0.085471	0.030787	0.106289	0	0.003300
2006	0.404165	0.01683	0.583378	5.90E-03	0.052945	0.485678	0.309428	0.076351	0.030578	0.123338	0	0.543104
2007	0.598696	0.020813	0.626239	0.00699	0.056140	0.414528	0.306478	0.077799	0.030279	0.132395	0	0.003527
2008	0.494413	0.019825	0.694712	0.008451	0.067999	0.462732	0.295997	0.076355	0.030010	0.139243	0	0.003501
2009	0.447507	0.021949	0.784214	0.010523	0.035177	0.481858	0.310178	0.074744	0.029865	0.160031	0	0.004400

4.3 Relations between ecological footprint diversity and development capabilities

Correlation analysis showed that ecological economic system development capability was correlated positively to ecological footprint diversity. So development capability of ecological economic system can be promoted by means of increasing diversity of lands use, using equally different types of land resources and improving efficiency of resource utilization.

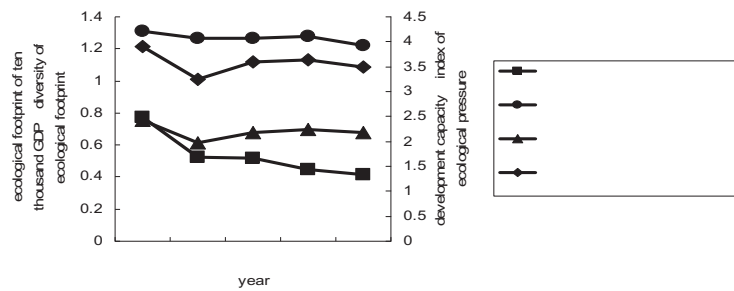


Figure 1 Dynamic trend of development capacity of Qinhuangdao during 2005-2009

As a whole, the pressure of human activities on the ecological environment had exceeded its carrying capacity. It indicated that ecological carrying capacity of Qinhuangdao can not support its ecological footprint requirement over the 5 years and showed a greater ecological deficit and ecological pressure. The mode of economic development of Qinhuangdao is resource consumption-based which is over exploited and utilized for natural resources. At the same time with the population increase and improvement of people's living standard, the high demands for resource consumption caused unsustainable development situation of Qinhuangdao.

According to correlation analysis, development capacity of eco-economic system was correlated negatively to ecological footprint, while positively correlated to the ecological footprint diversity. It is suggested that steps should be taken to increase diversity of the ecological footprint. It includes utilizing existing resources stock efficiently, paying attention to the development and utilization of renewable energy, developing circular economy, excavating city's own production potentials and promoting the harmonious development between human and nature.

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